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Correlation of angiographic and surgical findings in distal coronary branches

J PIDGEON,* T TREASURE,† N BROOKS, M CATTELL, R BALCON

From the London Chest Hospital, London

SUMMARY In 60 consecutive patients undergoing vein graft surgery the angiographic appearances of the coronary vessels were compared with those of the vessels at operation. On the basis of lumen diameter at the potential sites for grafting it was possible to predict with reasonable accuracy from examination of the angiogram which vessels were large enough to be grafted. Angiographic predictive accuracy was 82% and was similar both for vessels which filled normally and for those which filled by collaterals. The predictive value of the angiographic assessment was similar for branches thought to be too small (predictive value 74%) and for those considered sufficiently large (predictive value 85%) to receive a vein graft.

Disease of the vessel walls was found at surgery (66% of coronary branches examined) more frequently than was predicted from the angiographic appearances (33%). Previous necropsy studies have found a high prevalence of coronary atheroma in the population, yet normal angiographic appearances in the coronary arteries are not uncommon in patients undergoing investigation for suspected coronary disease. The present study showed that atheroma may be present in coronary vessels without encroaching into the vessel lumen, so that it is not evident on the angiogram. Coronary atheroma is thus present more often and is more widely distributed in the coronary tree than is indicated by coronary angiography.

Postmortem examination of the coronary arteries of patients who have previously undergone coronary angiography during life suggests that atheroma is more extensive than is apparent from the angiogram.[1] Although the magnitude of the stenosis estimated at angiography largely correlates with that determined at subsequent necropsy, angiography in life systematically tends to underestimate the degree of stenosis.[2–4] Patients in these studies may, however, be atypical in that they died of their coronary disease, or after surgical treatment for it, and thus represent the most severe extreme of the spectrum of the disease. We therefore undertook a study to correlate the extent of coronary atheroma with the angiographic appearances during life by examining the coronary vessels during bypass surgery. The study was concerned with the distribution of coronary atheroma, and no attempt was made to assess the degree of stenosis at operation.

The suspicion that atheroma is more widespread than indicated from examination of the angiogram is of interest both for epidemiologial reasons and because distally sited disease has a detrimental influence on subsequent graft patency.[5] Coronary atheroma is frequently found at necropsy of patients who have died of known non-cardiovascular causes and with no known history of ischaemic heart disease. Figures for the presence of atheroma vary from 77% for young servicemen[6] to 85% for civil servants.[7] The finding of normal appearances on angiography in up to 27% of patients undergoing investigation for suspected angina[8] or after myocardial infarction[9] seems surprising in this context. We looked for a possible explanation for this discrepancy by determining whether angiographically normal vessels contain atheroma when inspected at operation. We also aimed to determine how far it was possible to predict from the angiogram, on the basis of lumen diameter, which vessels—particularly those filled by collaterals—would be suitable for grafting.

Requests for reprints to Dr J Pidgeon, Royal Liverpool Hospital, Prescot Street, Liverpool L7 8XP.

*Present address: Royal Liverpool Hospital, Liverpool L7 8XP, Merseyside.

†Present address: Middlesex Hospital, London.

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Dr Cattell died recently.

Patients and methods

Sixty consecutive patients undergoing bypass graft surgery for coronary artery disease within four months of angiography were studied.

ANGIOGRAPHIC ASSESSMENT

Coronary angiograms were performed by hand injection of 5–10 ml Urografin (sodium diatrizoate 0·1 g/ml and meglumine diatrizoate 0·66 g/ml) in three views with a Siemens high resolution image intensifier. Cineradiographs were recorded on Agfa RPI 35 mm film at 25 frames/s.

Analysis was performed by consensus between three observers. The coronary artery branches assessed comprised the distal anterior descending, its diagonal branches, the lateral circumflex branches, and inferior left ventricular branches of the right coronary, including the posterior descending artery. The right coronary artery before the crux was also examined. The following features were recorded for all the coronary branches that could be identified: (a) the degree (to within 10% of lumen diameter) and site of the stenosis; (b) the presence or absence of vessel wall disease, as judged by the regularity of the angiographic outline of the distal branches; (c) whether the branch appeared sufficiently large to accept a vein graft (>1·0 mm); (d) the mode of filling of the branch, whether by normal antegrade flow or via collaterals; and (e) the presence of coronary artery calcification. In some vessels the presence or absence of disease of the wall could not be determined.

In addition, the diameter of the lumen of the branches was directly measured by one observer. The angiographic image was projected at about 10 times magnification and the diameter of the branches measured at the expected site for graft insertion. The measurements were calibrated by reference to the tip of the catheter, whose diameter was known. No correction was made for different projections.

SURGICAL ASSESSMENT

The findings at surgery were assessed by one observer (TT). For all the coronary branches that were accessible the following data were recorded: (a) the presence of visible or palpable arterial wall disease described as—(i) generalised thickening, (ii) atheroma in plaques, or (iii) confluent atheroma; (b) if a branch was large enough to receive a vein graft; and (c) the manner in which the assessment was made—(i) by palpation only, (ii) by visual inspection without opening the branch, or (iii) by inspection after the branch had been opened.

CORRELATION

The angiographic and surgical findings were then correlated for all such branches and (a) for branches which filled normally compared with those which filled via collaterals, and (b) according to the site of the branches within the coronary tree—that is, the right coronary artery system, the circumflex system, and the left anterior descending system. Failure to identify a branch at surgery was recorded. Angiographic and surgical assessments were made independently, each without the knowledge of the result of the other.

Angiographic predictive accuracy was calculated as the number of branches correctly assessed—that is, the agreement between angiographic and surgical assessment—divided by all branches correlated and was a measure of the ability of angiography to predict vessel size or presence of disease.

Angiographic predictive value for a particular feature was calculated as the number of branches showing the feature at angiography and confirmed at surgery divided by the number of branches showing the feature at angiography. This indicates the likelihood of an angiographic observation—for example, a branch large enough to graft—to be correct.

Statistical analyses were performed using Student's unpaired t test, the χ^2 test, and Fisher's exact probability test.

Results

Correlation analyses were possible for a total of 259 branches from 58 patients. Assessment at operation was by external inspection in 125, by inspection after arteriotomy in 118, and by palpation only in 16. Calcification was noted in 17 angiograms. The left main stem was affected in 10, left anterior descending artery in eight, right coronary artery in five, and circumflex artery in two. The distribution of significant (>50%) stenoses was: (a) left main in 12 (with accompanying three vessel disease in five, two vessel disease in five, and single vessel disease in two); (b) three vessel disease in 17; (c) two vessel disease in 19 (left anterior descending artery and right coronary artery in nine, left anterior descending artery and circumflex artery in five, and circumflex artery and right coronary artery in five); (d) single vessel disease in nine (left anterior descending artery in eight, right coronary artery in one); and (e) Iatrogenic left main dissection in one.

PRESENCE OF DISEASE

Correlation analysis was possible for 205 branches, and of these 135 (66%) were found to be diseased on inspection at surgery. At angiography 137 (67%) of the 205 branches appeared normal distally at potential graft sites, although there were stenoses proximally within the branches in 62. Eighty (58%) of these 137 angiographically normal distal branches were seen

to be diseased at surgery. Conversely, when branches appeared angiographically diseased (n=68), this was confirmed at surgery on 81% of occasions irrespective of the presence or absence of proximal stenoses. These figures yielded an angiographic predictive accuracy of 56%, and this assessment was not appreciably influenced by the mode of vessel filling seen on the angiogram (Fisher's exact test $p>0{\cdot}3$).

Of the 137 branches that appeared angiographically normal distally, 75 had no proximal stenosis within the branch and so appeared normal throughout, even though 37 (49%) were diseased at surgery. On 27 occasions the whole vessel system (left anterior descending artery, circumflex artery, and right coronary artery) was considered to be normal at angiography, and on 14 (52%) occasions these vessels were diseased at surgery. Thus coronary branches are frequently diseased when their angiographic appearance appears normal. At surgery branches within the left anterior descending artery (78%) and right coronary artery (70%) systems were diseased significantly more often (Fisher's two tail test $p<0{\cdot}002$) than in the circumflex system (37%).

SIZE OF CORONARY BRANCHES

Data for correlation were available from 240 branches. At surgery 163 (68%) of these were considered suitable for grafting. Of 171 branches considered at angiography to be sufficiently large to receive a vein graft, the surgical assessment was in agreement in 145 (angiographic predictive value 85%). Of 69 branches thought at angiography to be too small to graft, 51 were found to be unsuitable on surgical inspection (angiographic predictive value 74%). For all branches angiographic predictive accuracy of vessel size was 84%. The ability to predict which branches were large enough to receive a vein graft appeared to be similar whether the branch filled normally (predictive accuracy 84%) or via collaterals (predictive accuracy 78%) (Table 1). Branches that filled via collaterals were considered to be too small to graft at surgery more frequently (45%) than those filling normally (27%), and this difference was statistically significant (χ^2 test: $p<0{\cdot}001$).

The size of branches and the angiographic prediction of that size was examined according to the distribution of the branches within the coronary tree (Table 2). Angiographic predictive accuracy was not dependent on the site of a particular branch. The diagonal branches of the left anterior descending artery and the inferior left ventricular branches tended to be unsuitable for grafting more often than other coronary branches.

Table 3 shows the values for the direct measurements of the branch lumen diameters in each vessel territory. In each territory the mean diameter was found to be smaller for those branches that were considered to be unsuitable for grafting on surgical inspection than for those thought to be suitable. The difference between the two groups (graftable and non-graftable) reached significance for the diagonal branches of the left anterior descending artery, the

Table 1 *Influence of the mode of filling of coronary branches observed at angiography on assessment of distal branch size. Figures are numbers of branches*

Angiographic assessment of branch size	*Surgical assessment*		
	Graftable	*Not graftable*	*% Graftable*
Normal filling			
Large	116	19	
Small	9	27	73
Predictive accuracy	84%		
Filling via collaterals			
Large	29	7	
Small	9	24	55
Predictive accuracy	78%		

Table 2 *Assessment of size of branch lumens according to their site within the coronary tree*

Vessel territory	*No of branches assessed*	*% Graftable on surgical assessment*	*Angiographic predictive accuracy (%)*
Left anterior descending artery	50	90	77
Diagonal of left anterior descending artery	30	50	87
Circumflex artery	54	83	90
Right coronary artery	27	88	80
Inferior left ventricular branches			
Posterior descending artery	39	62	82
Other	40	24	73

Table 3 *Mean values (mm) ± 1 standard deviation of measured diameters of coronary branches from angiograms*

Vessel territory	*n*	*Surgical assessment*			*p**
		Graftable	*n*	*Not graftable*	
Left anterior descending artery	45	1·82 ± 0·57	5	1·62 ± 0·55	NS
Diagonal of left anterior descending artery	15	1·72 ± 0·39	15	1·13 ± 0·49	<0·01
Circumflex artery	45	2·03 ± 0·57	9	1·52 ± 0·59	<0·05
Right coronary artery	24	2·48 ± 0·85	3	2·00 ± 0·08	NS
Inferior left ventricular branches	34	1·74 ± 0·53	43	1·23 ± 0·44	<0·001

*Unpaired Student's *t* test

circumflex branches, and the inferior left ventricular branches (Student's unpaired *t* test).

FAILURE TO CORRELATE ALL BRANCHES

Two right coronary artery branches, 30 inferior left ventricular branches, three left anterior descending artery branches, and 29 diagonal branches were inaccessible to inspection at surgery. Forty eight (75%) of these 64 branches were considered to be too small for grafting at angiography. In 31 patients the correlation of circumflex branches was uncertain, and these data are therefore not included in the analysis.

Discussion

SIZE OF CORONARY BRANCHES

This study, like others,[5] has shown a good correlation between the angiographic and surgical assessment of the suitability of branches to receive a vein graft. On the basis of lumen diameter we attempted to predict whether the surgeon would elect to bypass a branch. Lumen diameter is, however, also an important determinant of subsequent graft patency. Up to 100% of branches with a diameter of less than 1·0 mm may occlude by one year.[5 10]

Our ability to predict suitability for grafting was similar both for branches filled normally and for those filled by collaterals, which is at variance with the observations of Partridge *et al.*[10] These workers found that in some severely stenosed or occluded vessels the lumen appeared small on the preoperative angiogram but later showed an apparent increase in diameter at reinvestigation after bypass. Rösch *et al*[11] were able to predict suitability for grafting for 96% of normally filled vessels, 76% for those filled both antegradely and retrogradely by collaterals, and 65% for those filled by collaterals from only one coronary artery.

In this study it was considered to be possible on most occasions, by both angiographic and surgical assessment, to insert grafts into the distal left anterior descending artery and right coronary artery before the crux. The ability to predict suitability for grafting is, therefore, of more practical importance for those other branches for which the chances of suitability are less.

Why angiographic assessment of the suitability for grafting should be more accurate than a direct measurement of vessel diameter is unclear. One explanation may be the lack of precision with which vessels may be measured, especially if the branches are faintly opacified or are small and thus contain relatively little contrast medium.

PRESENCE OF DISEASE

Our results agree with those of previous studies correlating necropsy and angiographic findings in indicating that patients with coronary atheroma have widely distributed disease, which is often underestimated by angiography. Various technical factors may account for the tendency of the angiogram to underestimate the extent and severity of the atheroma. These include the use of an inadequate number of projections, the presence of eccentric lesions, overlapping of vessels, and inadequate filling of branches after severe stenoses.[3 4] Our ability to predict vessel size with reasonable accuracy does not necessarily imply an equal ability to determine the magnitude of the stenosis. Indeed, where a vessel is diffusely affected by atheromatous changes, a stenosis may not be apparent despite the extent of the disease.[2] Since atheroma is a condition of the subintimal layer, inspection of the external surface of vessels at surgery may underestimate disease, which may be even more extensive than we found.

There is a discrepancy between the high prevalence of atheroma at necropsy in patients without previously diagnosed ischaemic heart disease and the lower prevalence (4–8%) of evidence of myocardial ischaemia in living patients.[12 13] Precise quantification of the extent of vessel wall involvement and measurement of the degree of narrowing at necropsy have shown that while atheromatous changes are often present in "normal" subjects they are much more severe in those believed to have died of their coronary artery disease.[14] Atheroma has been detected in the walls of vessels whose postmortem angiographic appearance is normal.[15]

The relatively frequent finding of normal angiograms in patients investigated for chest pain could be explained by the possibility that the vessel walls may be affected by atheroma which is not evident angiog-

raphically. Patients with angiographically normal vessels have a good prognosis[16] and so seldom come to necropsy. Four such patients were subsequently shown to have normal coronary arteries,[17 18] but in another report atheroma was found at necropsy in patients with normal angiograms in life.[19] Follow up angiography of patients with normal angiographic appearances initially has shown that stenosis may develop, implying the presence of previous disease.[20] Data from patients who require valve surgery would be helpful, but the extra manipulation of the heart required to examine the arteries at operation would not be justified.

CONCLUSION

The results of our study and others show that coronary atheroma may be present which does not encroach into the vessel lumen. We frequently found disease in branches with no proximal stenoses and normal appearances distally. This observation explains the discrepancy between postmortem and clinical evidence of coronary disease. Clinical manifestations of coronary artery disease probably relate to the presence of haemodynamically significant stenoses, and the prognosis in patients undergoing angiography is linked to the number and severity of these stenoses.[21] There is no evidence that prognosis is related to merely the presence of atheroma. Such atheroma may not be evident on the angiogram but may be found at necropsy.

The major indication for angiography is to determine the sites and degree of stenosis in order to assess the need for bypass or angioplasty. There is no indication at present to bypass diseased vessels in the absence of significant stenoses. A useful prediction of which branches are suitable for grafting can be made from an inspection of the angiogram.

References

1 Waller BF, Roberts WC. Amount of narrowing by atherosclerotic plaque in 44 nonbypassed and 52 bypassed major epicardial coronary arteries in 32 necropsy patients who died within one month of aorto-coronary bypass grafting. *Am J Cardiol* 1980; **46**: 956–62.

2 Arnett EN, Isner JM, Redwood DR, *et al.* Coronary artery narrowing in coronary heart disease. Comparison of cine-angiographic and necropsy findings. *Ann Intern Med* 1979; **91**: 350–6.

3 Murphy ML, Galbraith JE, de Soyza N. The reliability of coronary angiogram interpretation. An angiographic-pathologic correlation with a comparison of radiographic views. *Am Heart J* 1979; **97**: 578–84.

4 Schwartz JN, Kong Y, Hackel DB, Bartel AG. Comparison of angiographic and post-mortem findings in patients with coronary artery disease *Am J Cardiol* 1975; **36**: 174–8.

5 Lespérance J, Bourassa M, Biron P, Campeau L, Saltiel J. Aorta to coronary artery saphenous vein grafts. Preoperative angiographic criteria for successful surgery. *Am J Cardiol* 1972; **30**: 459–65.

6 Enos WF, Holmes RH, Beyer J. Coronary disease among United States soldiers killed in action in Korea: preliminary report. *JAMA* 1953; **152**: 1090–3.

7 Morris JN, Crawford MD. Coronary heart disease and physical activity of work. Evidence of a national necropsy survey. *Br Med J* 1958; **ii**: 1485–96.

8 Proudfit WL, Shirley EK, Sones FM Jr. Selective cine coronary arteriography. Correlation with clinical findings in 1,000 patients. *Circulation* 1966; **33**: 901–10.

9 Erlebacher JA. Transmural myocardial infarction with "normal" coronary arteries. *Am Heart J* 1979; **98**: 421–30.

10 Partridge JB, Brandt PW, Whitlock RM. The underfilled coronary artery; some pre- and post operative observations on recipient arterial quality and left ventricular function after coronary artery surgery. *Clin Radiol* 1978; **29**: 5–8.

11 Rösch J, Dotter CT, Antonovic R, Bonchek L, Starr A. Angiographic appraisal of distal vessel suitability for aortocoronary bypass graft surgery. *Circulation* 1973; **48**: 202–12.

12 Rose G, Marmot MG. Social class and coronary heart disease. *Br Heart J* 1981; **45**: 13–9.

13 Froelicher VF Jr, Thomas MM, Pillow C, Lancaster MC. Epidemiologic study of asymptomatic men screened by maximal treadmill testing for latent coronary artery disease. *Am J Cardiol* 1974; **34**: 770–6.

14 Roberts WC, Jones AA. Quantitation of coronary arterial narrowing at necropsy in sudden coronary death. *Am J Cardiol* 1979; **44**: 39–45.

15 Blumgart HL, Schlesinger MJ, Davis D. Studies on the relationship of the clinical manifestations of angina pectoris, coronary thrombosis, and myocardial infarction to the pathologic findings. *Am Heart J* 1940; **19**: 1–91.

16 Proudfit W, Bruschke AVG, Sones FM Jr. Clinical course of patients with normal or slightly or moderately abnormal coronary arteriograms: 10 year follow up of 521 patients. *Circulation* 1980; **62**: 712–7.

17 Bemiller CR, Pepine CJ, Rogers AK. Long-term observations in patients with angina and normal coronary arteriograms. *Circulation* 1973; **47**: 36–43.

18 Eliot RS, Bratt G. The paradox of myocardial ischemia and necrosis in young women with normal coronary arteriograms. Relation to abnormal hemoglobin-oxygen dissociation. *Am J Cardiol* 1969; **23**: 633–8.

19 Forsberg SA, Alestig K, Bjure J, *et al.* Post-mortem, coronary arteriographic, clinical and electro-cardiographic findings in 80 patients investigated with coronary arteriography. *Acta Med Scand* 1971; **189**: 463–70.

20 Marchandise B, Bourassa M, Chaitman BR, Lespérance J. Angiographic evaluation of the natural history of normal coronary arteries and mild coronary atherosclerosis. *Am J Cardiol* 1978; **41**: 216–20.

21 Proudfit WL, Bruschke AVG, Sones FM Jr. Natural history of obstructive coronary artery disease. Ten-year study of 601 non-surgical cases. *Prog Cardiovasc Dis* 1978; **21**: 53–78.